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RESEARCH & ENGINEERING DIRECTORATE

ENGINEERING DIVISION

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FINAL REPORT - PHASE I

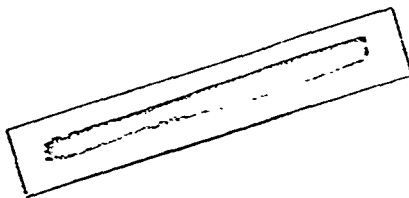
BY

JAMES DeGROOT

DATE OF REPORT: 29 JUNE 1962

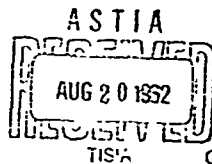
DEPARTMENT OF THE ARMY  
PROJECT NO. 593-21-062

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ORDNANCE TANK-AUTOMOTIVE COMMAND  
CENTER LINE, MICHIGAN

SECURITY CLASSIFICATION: UNCLASSIFIED



ENGINE CORROSION STUDY

ORDNANCE TANK AUTOMOTIVE COMMAND

RESEARCH & ENGINEERING DIRECTORATE

ENGINEERING DIVISION

MATERIALS BRANCH

COATINGS & PETROLEUM SECTION

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FINAL REPORT OF PHASE I  
ENGINE CORROSION STUDY  
ON  
INSTALLED ENGINES  
AS A COMPONENT OF A COMBAT VEHICLE  
IN OUTDOOR STORAGE  
AT ANNISTON ORDNANCE DEPOT  
ANNISTON, ALABAMA

CONDUCTED FROM  
JULY 1958 - OCTOBER 1961  
PROJECT ENGINEER JAMES DeGROOT  
OTAC-ORDMC-REM.3  
FIELD PROJECT COORDINATOR JAMES WALLACE  
ANNISTON ORDNANCE DEPOT

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## ABSTRACT

### PURPOSE

To attempt to increase the reprocessing cycle of installed engines in vehicles stored outdoors from the presently used one year to a minimum of three years. Despite improvements in application techniques, corrosion still occurs primarily in the cylinder area in less than one year. By the use of newly developed or improved presently used preservative materials it is possible that maintenance in storage reprocessing operations can be greatly reduced.

### RESULTS

VCI oil used in the test proved far superior to the presently used MIL-L-21260 oil after a minimum of three years outdoor storage under actual conditions. Of 24 cylinders (2 test engines) using the VCI oil 17 were corrosion free after three years. The other 7 cylinders developed spotty and not too severe corrosion during the third year of storage.

MIL-L-21260 oil displayed sufficient corrosion on 12 of 24 cylinders to question satisfactory operation of the engine after reassembly without considerable rework and/or salvage. Half of the cylinders showed corrosion in the first year.

### CONCLUSIONS

There was no apparent attack from the VCI oil or VCI crystals on non-ferrous or non-metallic components of the engine. The two greatest causes of corroded cylinders of engines are:

- a. Temperature conditions that produce alternate condensation and evaporation of moisture.
- b. Combustion products producing an acidic environment.

#### ACKNOWLEDGEMENTS

The assistance, advice, suggestions and contributions of the Anniston Ordnance Depot, Anniston, Alabama were of great value in this program. The interest, ability and cooperation of many of their personnel was both stimulating and inspiring.

Their participation in the many operations so necessary for a program of this scope and magnitude was a united effort. Every activity and individual accomplished their part in a most efficient manner. It was a privilege to work with these many fine people. They deserve a lot of recognition for the accomplishments contained herein.

A special note of thanks to James Wallace, Packaging Specialist, who did a fine job for the depot as project coordinator.



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### SUMMARY AND CONCLUSIONS

1. Very little difference in performance before and after corrosion was noted. After at least three years of outdoor storage only one of 8 test engines would not start. This failure was attributed to improper timing and not corrosion. Minor failures on other engines were not caused by corrosion. It is of interest to note that a penalty in engine performance caused by corrosion is not too significant, based on a 90 minute test run as used in this project. For any future projects of this type at least a 50 hour test run is recommended. Only then will corrosion show the deficiencies worth being concerned about, such as lower compression, increased ring wear and higher oil consumption. Where corrosion is severe enough, ring breakage could occur. Therefore, it is definite that the less corrosion prevalent in the cylinder area, the better for all concerned.

2. There was no apparent attack from the VCI oil or VCI crystals on non-ferrous or non-metallic components of the engine.

3. VCI oil from the one source used in this test gives much better protection than the presently used MIL-L-21260 preservative oil.

4. The two greatest causes of corroded cylinders of engines are:

a. Temperature conditions that produce alternate condensation and evaporation of moisture.

b. Combustion products producing an acidic environment.

NOTE: See Pages 35 through 38 for further conclusions.

### RECOMMENDATIONS

As a result of the most satisfactory performance of VCI oil under actual field conditions, the following recommendations are made:

a. Set up a fleet test of vehicles in storage with an equal amount of engines processed with VCI oil from at least three sources. Inter-service participation would be desirable. Actual performance under realistic field conditions could be evaluated relative to important characteristics of each VCI oil such as:

(1) Vapor pressure - Too high means short service life of the vapors. Too low will produce inadequate distribution of the vapors.

(2) Neutralization of acidic conditions.

(3) Toxicity.

(4) Compatibility.

(5) Solubility.

(6) Water displacement and stability.

(7) Quality and life of vapor phase and contact preservation.

b. Qualification people for VCI oil specifications resolve their present differences of opinion and come up with one coordinated document in which all interested sources agree.

c. VCI cannot be considered practical as an operating oil from many viewpoints, however the possibility of adding 5 to 20% of these oils to the presently used operating oils theoretically offers good potential for a unique way of preservation. This type work could be included in the fleet test recommended.

## INTRODUCTION

### BACKGROUND AND HISTORY:

An OTAC staff study dated 21 June 1956 reveals that engines preserved by current techniques and materials show corrosion in a relatively short time. Areas in the cylinder above piston travel zone were of particular concern. As a result of the staff study improvements in the techniques of application of preservative oils were recognized as necessary and therefore changes in the specification were made. Despite these improvements, corrosion is still possible as a result of human error, shortage of personnel and equipment, infrequent reprocessing or maintenance in storage, inadequate materials and improper use of existing or improved materials.

### PURPOSE OF TEST:

This project will attempt to determine the extent of possible improvements attainable by the use of new and/or existing permanent type protective coatings with new and/or improved preservative oils so that inadequacy due to any of the above reasons are either entirely eliminated or greatly reduced.

### SCOPE OF PROJECT:

Sufficient laboratory testing has been accomplished to indicate the use of permanent type coatings such as Electrofilm 4856 or phosphate treatment alone on the interior surfaces of the cylinders provides considerably more resistance to corrosion. It is felt that sufficient work is already in process on gymnastication and dehumidified storage. Short range tests such as those that are conducted with laboratory equipment like humidity and salt spray cabinets or preservative oils applied to panels and disassembled engine cylinders have provided guide lines for more extensive testing. In these short range tests, the advantages of much quicker results are recognized, however, the question of simulated conditions has to be taken into account. The question always arises, would the same results be achieved under actual conditions where products of combustion are prevalent as the cylinder would be an integral part of the engine with the sealed chamber. Also exposure to the nature elements is far different than laboratory equipment not to mention the variations that can occur even between exposure on spare engines and those installed as a component of a vehicle.

Test engines No's 1, 2, 3 & 4 were rebuilt by the Experimental Division, Detroit Arsenal. In order to assure corrosion free engines, cylinders, pistons, rings, intake valves and exhaust valves were either reworked or replaced as deemed necessary. The same was accomplished on test engines No's 5, 6, 7 & 8 by Anniston Ordnance Depot. All eight rebuilt test engines were then installed into

vehicles and run 100 miles on the dirt test track at Anniston Ordnance Depot. All test engines were then processed in accordance with the materials outlined in the following chart applicable to each engine. Application techniques as outlined in MIL-STD-634 were carefully adhered to with the exception of the VCI plugs which are not covered in such publication.

Test plans call for a boroscope examination of each cylinder after the first and second year of storage. After the third year of storage test engines will be removed from the vehicle, completely disassembled and carefully evaluated. The purpose and objective of this project to evaluate various combinations of preservative oils, volatile corrosion inhibitor oils, volatile corrosion inhibitor plugs, phosphate and electrofilm finishes will be fulfilled with the hope that maintenance care and preservation expenditures can be greatly reduced by definite recommendations of the best preservative materials or combinations thereof. Completion date estimated to be October 1961.

#### PHASE II

Phase I involved 8 test engines installed into 8 combat vehicles. Actual conditions of vehicle operation, processing and storage were simulated in Phase I, however considerable expense was necessary for such method of evaluation. Therefore limited funds restricted the evaluation of only a few of the most promising preservative materials under such test conditions. Other services have conducted field tests with considerable success on engines exposed to the elements in wooden boxes, thereby simulating to a certain degree protection afforded to installed engines in equipment such as aircraft tanks, trucks, etc. Therefore Phase II was implemented in April 1959 to include several more newly developed or improved currently used preservative materials utilizing 18 test engines and 9 preservative materials. (2 engines for each material). Higher authority did not approve the loan of 18 vehicles for 3 years, the duration of the test. Therefore engines were to be placed under the protection of reusable exterior wood containers after rebuild, 10 hour run on a dynamometer and processing. Two annual partial teardown evaluations have been accomplished. Third and final complete teardown evaluation will be completed in February 1963.

#### PHASE III

Sufficient information and data have been ascertained from Phase I & II to warrant a third phase. When Phase I of this study started in 1958 only one VCI oil was available. There are now at least three with improvements in contact inhibitors, vapor space inhibitors and acid neutralizers. Only recently a specification was issued. Also in the last four years improvements have been attained in processing techniques. Past difficulties in engine

preservation were due in part to this factor. Therefore it is deemed advisable to evaluate the standard preservative oil with improved application techniques and still maintain a control material. Plans are now finalized to utilize 12 more boxed engines using the same rebuild operations and storage conditions as Phase II. Materials to be tested will include at least four VCI preservative oils, one special spark plug type container of VCI crystals and one standard MIL-L-21260 oil with the latest developed application techniques. Plans now call for this phase to be implemented in the early fall of 1962. Areas of consideration for future work include diesel engines, multi-fuel engines and the possibility of adding varying amounts of VCI oil to the standard preservative operational oil.

# GENERAL SPECIFICATIONS OF TEST ENGINES NO's. 1,3,5,6,7 & 8

12 Cylinder, V type, Gasoline.

Coolant - Air

Cycle - 4 Stroke.

Bore - 5.75 in.

Stroke - 5.75 in.

Displacement - 1791.94 cu.in.

Compression Ratio - 6.5:1

Gross h.p. - 810 @ 2800 RPM

Max. Torque - 1580 lb.ft. @ 2200 RPM

Valve Arrangement - Overhead Camshaft - 2 valves per cylinder.

Max. BMEP - 132 psi @ 2200 RPM

Max. Engine Air Demand - 1280 cfm @ 2800 RPM

## DIMENSIONS

Length - 73.92 in.

Width - 59.82 in.

Height - 40.65 in.

Weight (Dry) - 2605 lbs.

Oil Capacity - 18 gal.

NOTES - Test Engines No's 1, 3, 5 & 6 Fuel Injection Type.

" " " 7 & 8 Carburetor Type.

Cylinders are individually replaceable units, arranged in 2 banks numbered 1 to 6 on the right and 1 to 6 on the left when viewed from the accessory end or front.

## GENERAL SPECIFICATIONS OF TEST ENGINES NO's 2 &amp; 4

6 Cylinder, Horizontal, Opposed, Supercharged, Carbureted.

Coolant - Air

Cycle - 4 Stroke

Fuel - Gasoline - MIL-G-3056

Bore - 5.75 in.

Stroke - 5.75 in.

Displacement - 895.9 cu.in.

Compression Ratio - 5.5:1

Gross h.p. - 500 @ 2800 RPM

Max. Torque - 955 lb.ft. @ 2200

Valve Arrangement - Overhead camshaft, 2 valves per cylinder.

Max. BMEP - 161 psi @ 2400 RPM

Max. Engine Air Demand - 845 cfm @ 2800 RPM

DIMENSIONS

Length - 47.43 in.

Width - 51.56 in.

Height - 34.81 in.

Weight (Dry) - 1861 lbs.

Oil Capacity - 11 gal.

NOTES - Cylinders are individually replaceable units, arranged in two banks, numbered 1, 3 & 5 on the right and 2, 4 & 6 on the left when viewed from the accessory end or front.



### PROCESSING PROCEDURES

Test engines #1 thru 6 were processed in the following manner before going into storage.

A container with two compartments, one filled with oil, Specification MIL-L-644, the other with fuel, Specification MIL-G-5572 shall be used. Fuel line from the container shall be connected to the vehicle fuel line at an accessible point which is most distant from the engine. For injection type engine, the injector fuel return line shall be disconnected at quick disconnect coupling and the female quick disconnect coupling on the line from the container shall be connected to the male quick disconnect fitting. For carburetor type engines, the fuel intake line shall be disconnected from the fuel tank side of engine driven fuel pump and the female quick disconnect coupling on the line from the container shall be connected to the male quick disconnect fitting. Container regulator valve shall be turned to the FUEL position. Engine shall be started and operated at a minimum speed for one minute, then accelerated to three-fourths speed without load. Container regulator valve shall be turned to OIL position. At the instant engine begins to misfire, the ignition or magneto switches shall be turned to the OFF position. Fuel line of the container shall be disconnected and vehicle fuel line reconnected. Engine shall be cooled to 100°F or below measured at spark plug gasket surfaces of all cylinders. Spark plugs shall be removed and handled carefully to avoid damage to electrodes and threads. Two ounces of preservative oil, as indicated on each engine graph sheet were atomized sprayed into each cylinder through the spark plug opening while engine is being cranked with starting motor. Two additional ounces of the same test oils were then atomized sprayed into each cylinder without cranking. Threaded ends of spark plugs shall be reinstalled and engine not to be cranked anymore.

Test engines #7 and 8 had only the left bank of cylinders atomized sprayed through the spark plug openings with the designated test oil. Plastic plug containers each containing 4 grams of VCI crystals (1 to a cylinder) were inserted into the spark plug opening. Dry compressed air was then applied to the outer end of the plug so as to force the VCI crystals into the combustion area of the cylinder. Plastic plugs were then removed and spark plugs reinstalled.

**NOTE** - Before any processing as noted above is accomplished engine crankcases are filled to operating level with preservative oil MIL-L-21260, grade determined by vehicle and operating conditions.

STAGES OF CORROSION  
FROM  
MIL-STD-634(ORD) COMBAT VEHICLES, INSPECTION,  
CARE AND PRESERVATION DURING STORAGE OF

Stages of Corrosion	Identification Stage Description
Stage 1	Discoloration, staining. No direct visual evidence of pitting, etching or other surface damage.
Stage 2	Loose rust, black or white corrosion accompanied by minor etching and pitting of surface affected. No scale, or tight rust.
Stage 3	Rust, black or white corrosion accompanied singly or in combination with etching, pitting or more extensive surface damage. Loose or granular condition.
Stage 4	Rust, black or white corrosion progressed to the point where fit, wear function or life of the item has been affected. Powdered or scaly condition, with pits or irregular areas of material removed from surface of item.

VISIT OF TASK GROUP

On 11 and 12 October 1961 the service wide Task Group on Preservatives and Preservation visited Anniston Ordnance Depot. This is a group of about 20 individuals, scientists, engineers, technicians and specialists representing the Army, Navy, Air Force, Marine Corps and Department of Defense primarily interested in all the technical aspects of preservation. Quarterly meetings are held usually at some installation where some program or activity is of sufficient interest to all. This project had been a topic of discussion at their previous meetings.

The Ordnance Corps was honored by the group's decision to hold their 1961 fall meeting at the Anniston Ordnance Depot to view first hand this Ordnance Tank-Automotive Command Engine Corrosion Study. They held their regular business meeting the first day 11 October 1961. The second day 12 October 1961 the entire group plus four more service representatives participated in the third annual evaluation of the partially disassembled 8 test engines. Formal and informal discussions were held before, during and after the actual inspection of the engines and various components. Comments, suggestions and constructive criticism offered by various members of the group were most helpful especially for future concepts. The Task Group is under the capable chairmanship of David Bootzin, ORDBC-9320-DB, Rock Island Arsenal Laboratories while the duties of Secretary are most efficiently handled by Gerald Reinsmith, ORDOW-TB, Ordnance Weapons Command, Rock Island, Illinois. Everyone agreed that Anniston Ordnance Depot was the perfect host for the two day conference.

CODE FOR ABBREVIATIONS USED FOR DIAGRAM  
SHEETS OF ENGINES AND CYLINDERS WHERE LACK  
OF SPACE NECESSITATES SUCH

Stage (referring to degree of corrosion) - #

Corrosion	- Corr
Cylinder	- Cyl
Entire	- Ent
Wide	- W
Long	- L

CODE FOR NUMBERS AND LETTERS  
WITHIN CIRCLES ON DIAGRAMS OF CYLINDERS

E - Electrofilm Coated Cylinders.

W - West Coast Application of Electrofilm (Parent Company)

D - Detroit Application of Electrofilm (Licensee)

1L-6L - Number of Cylinder L - Indicates Left Bank.

1R-6R - Number of Cylinder R - Indicates Right Bank.

P - Phosphate Coated Cylinders.

B - Bare Cylinders - No Permanent Type Coating.

### EXPLANATORY NOTES FOR CYLINDER REMOVAL

Some cylinders were removed for the following reasons, during the first and second annual evaluations.

- a. To compare the naked eye visual inspection to results obtained by the boroscope.
- b. To verify condition of the cylinder, especially where any difference of opinion exists between three individuals after using the boroscope.
- c. Some cylinders have the pistons at the top of the compression stroke, hence nothing can be seen with the boroscope.

### INFORMATION ON ANNUAL EVALUATIONS

The next 33 pages (13 thru 46) in words and diagrams show results of the three annual evaluations. The first and second year evaluations were confined to partial disassembly of the test engines. The third year and final evaluation was a complete disassembly of the test engines, inspection of components, reassembly and brief test run for efficiency of operation. Each evaluation is divided into three areas of information namely: (a) General Summary, (b) Detailed Summary, (c) Graphical Summary.

First Annual Evaluation - Pages 13 thru 22

Second " " - " 23 " 34

Third " " - " 35 " 46

The general and detailed summary of the third annual evaluation (Pages 35 thru 46) naturally supplements the brief summary and corrections shown on Page 1.

### GENERAL SUMMARY OF FIRST ANNUAL EVALUATION

Every cylinder in each engine was boroscope inspected by three individuals. Observations were discussed periodically. One cylinder from each bank of cylinders of all engines was removed for inspection with the naked eye, so comparison of results could be made with boroscope findings.

All engines processed with MIL-L-21250, Grade 2 the present engine preservative oil, displayed from 1 to 7 corroded cylinders most of which had reached the stage 3 type of corrosion.

No difference could be ascertained in protective qualities between low and high limit MIL-L-21250 oils.

The use of permanent type coatings on the piston travel area such as phosphate or electrofilm prior to processing with the standard preservative oil offers little added protection, when compared to the bare cylinders with the same oil. It was noted that most of the coating material had been removed on the 100 mile test track run.

Volatile Corrosion Inhibitors either in oil or crystal form performed remarkably well. The four AV-1790 engines processed with VCI materials produced 48 corrosion free cylinders, after 14 months outdoor storage.

VCI crystals when blown in the cylinders have a tendency to build up especially at the top of the cylinder. This condition would prove troublesome when considering the minute openings of injector nozzles of fuel injection and diesel engines. This condition was caused by the use of air pressure to the VCI crystal plugs after they had been inserted in the spark plug openings in accordance with the supplier's instructions. The omission of the air pressure for blowing the crystals in the cylinder would rectify this condition. It would then be interesting to see if sufficient vapors would be released into the cylinder area to perform as well. This will be checked in another phase of the project.

The partial disassembly only permitted a partial visual inspection of the valves, rings, pistons and other components. Past experience reveals the cylinder interior walls as the most susceptible to corrosion, hence the emphasis on this area at this time.

DETAILED SUMMARY OF FIRST ANNUAL EVALUATION

## Engine #1 - Low limit MIL-L-21260 Grade 2

- 5 of 12 cylinders remained corrosion free for one year
- 7 of 12 cylinders exhibited stage 3 corrosion in areas ranging from 1/2" to 1" wide and from 180° - 360° of the circumference of the piston travel area.

## Engine #2 - High limit MIL-L-21260 Grade 2

- 4 of 6 cylinders remained corrosion free for one year
- 1 of 6 cylinders showed stage 3 corrosion, 1" wide for 300° of the circumference of the piston travel area.
- 1 of 6 cylinders showed stage 3 corrosion 1/8" wide and 1" long.

## Engine #3 - High limit MIL-L-21260 Grade 2

- 7 of 12 cylinders remained corrosion free for one year
- 2 of 12 cylinders displayed stage 2 corrosion for an area of 1" x 4" in piston travel area.
- 1 of 12 cylinders displayed stage 3 corrosion in various spots over the entire piston travel area.
- 2 of 12 cylinders showed stage 3 corrosion for 1"-1-1/2" wide from 270°-360° of the circumference of the piston travel area.

## Engine #4 - Low limit MIL-L-21260 Grade 2

- 5 of 6 cylinders remained corrosion free
- 1 of 6 cylinders exhibited stage 3 corrosion of 1" wide for 300° of the circumference of the piston travel area.

## Engine #5 - VCI Oil.

- All 12 cylinders free of corrosion.

## Engine #6 - VCI Oil.

- All 12 cylinders free of corrosion.

## Engine #7 - Left Bank of 6 cylinders VCI plugs plus low limit

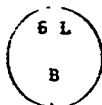
MIL-L-21260 Oil, Grade.

- Right Bank - VCI plugs only, no oil through spark plug openings.
- All 12 cylinders remained corrosion free.

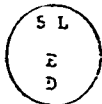
## Engine #8 - Same as #7

- All 12 cylinders remained corrosion free.

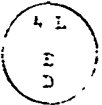
NOTE - Detailed graphical sheets on each engine and each cylinder follow.



No corrosion



#3 Corr 1" x for 360°



#3 Corr 1" x for 360°



#3 Corr 1" x for 360°



No corrosion



#3 Corr 1-1/2" x for 270°

Tank, combat, F.T. w/90  
MM, Gun, M48A1  
USA NR. 30177206

First Insp. 9-15-59

This is the results of  
the first inspection.

CODE FOR CYLINDERS

E - Electrofilm  
D - Detroit Licensee  
W - West Coast  
B - Bare  
1 - 6 Hr. of cylinders  
L - Left Bank  
R - Right Bank

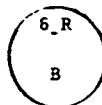
100 mile run of M48A1  
vehicle completed  
6-27-58.

Processed with Low Limit  
Grade 2, MIL-L-21260 Oil

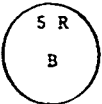
Pulled: This cylinder  
removed.

All cylinders Boroscoped

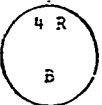
Date Processed: 7-2-58



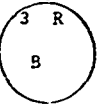
#3 Corr in spotty areas.



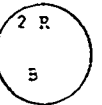
Spotty #3 Corr near top for 180°



No corrosion

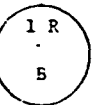


#3 Corr 1/2" x at top for 180°



Pulled

No corrosion

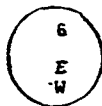


No corrosion

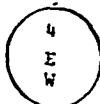
ACCESSORY END



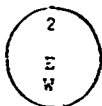
ENGINE NR. 2 AOS 895-3 SERIAL NR. 8207



No corrosion



No corrosion

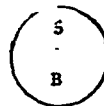
#3 Corr near top 1" L  
and 1/8" WGun, Self-Propelled, F.T.  
Twin 40MM, M42  
USA NR. 1ZF 881

First Insp. 9-15-59

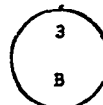
This is the results of  
the first inspection.CODE FOR CYLINDERSE - Electrofilm  
W - West Coast  
B - Bare100 mile run of M42  
vehicle completed  
6-27-58.Processed with: High  
Limit Grade 2 MIL-L-  
21260 Oil.Pulled: This cylinder  
removed.

All cylinders Boroscoped

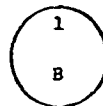
Date Processed: 7-2-58



No corrosion

#3 Corr at top 1" W for  
300°

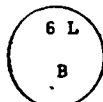
Pulled



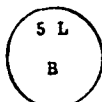
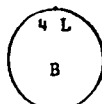
No corrosion

ACCESSORY END

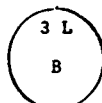
ENGINE NR. 3 AVI-1790-7C SERIAL NR. 26003



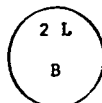
No corrosion

#3 Corr near top 1" W  
for 270°

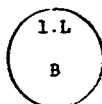
No corrosion

#3 Corr near top 1-1/2"  
W for 300°

Pulled



No corrosion



#3 Corr Spotty areas

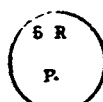
Tank, combat, F.T.  
w/90 MM Gun, M48A1  
USA NR. 9A1196

First Insp. 9-15-59

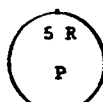
This is the results of  
the first inspection.CODE FOR CYLINDERSP - Phosphate  
B - Bare  
1 - 6 Hr. of cylinders  
L - Left Bank  
R - Right Bank100 mile run of M48A1  
vehicle completed  
6-27-58.Processed with: High  
Limit Grade 2 MIL-L-  
21260 OilPulled: This cylinder  
removed.

All cylinders Boroscoped

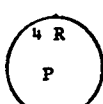
Date Processed: 7-2-58



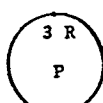
#2 Corr 1" W x 4" L



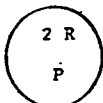
No corrosion



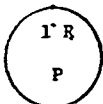
#2 Corr 1" x 4"



No corrosion



No corrosion



No corrosion

ACCESSORY END

ENGINE NR. 4 AOS-895-3 SERIAL NR. 4967

6

B

No corrosion

Cun, Self-Propelled, F.T.  
Twin 40MM, M42  
USA NR. 12D112

First Insp. 9-15-59

This is the results of  
the first inspection.

CODE FOR CYLINDERS

P - Phosphate  
B - Bare  
1 - 6 Nr. of cylinders

100 mile run of M42 Veh-  
icle completed: 6-27-58  
Processed with: Low Limit  
Grade 2 MIL-L-21260 Oil

5

P

No corrosion

4

B

No corrosion

Pulled: This cylinder  
removed.

Date Processed: 7-2-58

3

P

No corrosion

2

B

#3 Corr at top 1" W  
for 300°

Pulled

1

P

No corrosion

ACCESSORY END

ENGINE NR. 5 AVI-1790-7C SERIAL NR. 21040

6L

B

No corrosion

5 L

B

No corrosion

4 L

B

No corrosion

3 L

B

No corrosion

2 L

B

No corrosion  
Pulled

1 L

B

No corrosion

Tank, combat, F. T.  
w/90 MM Gun, M48A1  
USA NR. 30177800

First Insp. 9-15-59

This is the results of  
the first inspection.CODE FOR CYLINDERSB - Bare  
1 - 6 Nr. of cylinders  
L - Left Bank  
R - Right Bank100 mile run of M48A1  
vehicle completed  
9-28-58

Processed with: VCI Oil

All cylinders Boroscoped

Date Processed: 9-29-58

ACCESSORY END

6 R

B

No corrosion

5 R

B

No corrosion

4 R

B

No corrosion

3 R

B

No corrosion

2 R

B

No corrosion  
Pulled

1 R

B

No corrosion

ENGINE NR. 6 AVI-1790-7C SERIAL NR. 16586

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30177735

First Insp. 9-15-59

This is the results of  
the first inspection.CODE FOR CYLINDERS

B - Bare  
1 - 6 Hr. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-58

Processed with: VCI Oil.

There were no cylinders  
removed.

All cylinders Boroscoped

Date processed: 9-29-58

6 L

B

No corrosion

5 L

B

No corrosion

4 L

B

No corrosion

3 L

B

No corrosion

2 L

B

No corrosion

1 L

B

No corrosion

5 R

B

No corrosion

5 R

B

No corrosion

4 R

B

No corrosion

3 R

B

No corrosion

2 R

B

No corrosion

1 R

B

No corrosion

ACCESSORY END

ENGINE NR. 7 AV-1790B SERIAL NR. 18620

6 L

B

No corrosion

5 L

B

No corrosion

Pulled

4 L

B

No corrosion

3 L

B

No corrosion

2 L

B

No corrosion

1 L

B

No corrosion

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30173160

First Insp. 9-15-59

This is the results of  
the first inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 Nr. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-58.

1 - 6 Left Bank cylin-  
ders processed with: Low  
Limit Grade 2 MIL-L-  
2126C plus V.C.I. Plugs  
in spark plug openings.

Pulled: This cylinder  
removed.

All cylinders Beroscoped

Date processed: 9-29-58

6 R

B

No corrosion

5 R

B

No corrosion

4 R

B

No corrosion

3 R

B

No corrosion

2 R

B

No corrosion

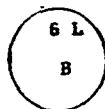
1 R

B

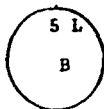
No corrosion

ACCESSORY END

ENGINE NR. 8 AV-1790B SERIAL NR. 51108

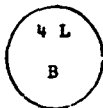


No corrosion

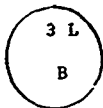


No corrosion

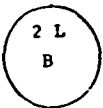
Pulled



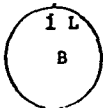
No corrosion



No corrosion



No corrosion



No corrosion

Tank, Combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 9A1195

First Insp. 9-15-59

This is the results of  
the first inspection.

Code For Cylinders

B - Bare  
L - Left Bank  
R - Right Bank  
1 - 6 Nr. of cylinders

100 mile run of M48A1  
vehicle completed  
9-29-58

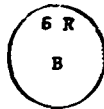
1 - 6 Left Bank cylinder  
processed with: Low  
Limit Grade 2 MIL-L-  
21260 plus V.C.I. Plugs  
in Spark Plug openings.

1 - 6 Right Bank cylinder  
processed with: VCI  
Plugs only, no oil thru  
spark plug openings.

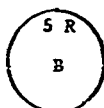
Pulled: This cylinder  
removed.

All cylinders Boroscoped

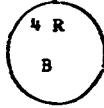
Date processed: 9-29-58



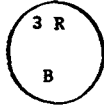
No corrosion



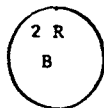
No corrosion



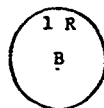
No corrosion



No corrosion



No corrosion



No corrosion

ACCESSORY END

#### GENERAL SUMMARY OF SECOND ANNUAL EVALUATION

Every cylinder in each engine was boroscope inspected by three individuals. Individual cylinders in some cases were completely removed for naked eye visual inspection, where any doubt or difference of opinion existed on the boroscope examination.

All engines processed with MIL-L-21260 preservative oils displayed at least 50% of the cylinders corroded, most of which had reached the stage 3 type.

With the MIL-L-21260 processed engines, cylinders that had displayed corrosion after the first annual inspection, had increased in severity and area affected. Also some cylinders not corroded after the first year were now affected.

The difference between the preservative qualities of low limit and high limit MIL-L-21260 oils was noticeable, indicating better results with material considered in the higher bracket of qualification.

The use of permanent type coatings such as phosphate or electrofilm on the cylinder walls prior to processing with the standard preservative oil (MIL-L-21260) offers little added protection, when compared to the bare uncoated cylinders, processed with the same oil. Observation indicated that most of such type coatings had been removed on the 100 mile test run before the original processing.

Practically all interior cylinder surfaces appeared quite dry with little or no evidence that oil had been atomized through the spark plug openings. This indicates the drain off characteristics of the oils used especially on vertical surfaces over a long period of time.

VCI oil (Eng #5 & 6) appeared best as no corrosion was found on any of the 24 cylinders after two years' storage. The fantastic part is that this is the second time in two years that the engines have been removed from the vehicles and set around for days with one spark plug removed from each cylinder. Apparently the contact and volatile protection was not too adversely affected by the excessive handling of the engines necessary to accomplish the evaluations.

VCI crystals (Eng. #7 & 8) in combination with MIL-L-21260 oil through the spark plug openings displayed only 3 of 12 cylinders with corrosion which had developed during the second year of storage and was confined to small areas. It was noted that the crystals were prevalent on the interior surfaces of the cylinder and when oil had been atomized through the spark plug openings there was a tendency of build-up in some areas of the two materials. In fact, through a boroscope these areas had the appearance of corrosion.



GENERAL SUMMARY OF SECOND ANNUAL EVALUATION

Only when the cylinders were removed for visual inspection, was it discovered that corrosion did not exist in these areas. This could be another potential trouble area when considering the minute openings of injector nozzles of fuel injection and diesel engines.

VCI crystals without MIL-L-21260 oil atomized through the spark plug openings likewise produced only 3 of 12 cylinders with corrosion developed during the second year of storage and again this corrosion was only in small areas.

DETAILED SUMMARY OF SECOND ANNUAL EVALUATION

## Engine #1 - Low limit MIL-L-21260 Grade 2

- 2 of 12 cylinders remained corrosion free for two years
- 2 of 12 cylinders exhibited stage 3 corrosion on the entire piston travel area.
- 1 of 12 cylinders had spotty stage 1 and 2 corrosion on the entire piston travel area.
- 4 of 12 cylinders displayed stage 3 corrosion in areas ranging from 1/2" to 1" wide and from 180°-360° of the circumference of the piston travel area.
- 3 of 12 cylinders displayed small areas of stage 1 and 2 corrosion ranging from 1/4" to 1" wide up to 60° of the circumference of the piston travel area.

## Engine #2 - High limit MIL-L-21260 Grade 2

- 3 of 6 cylinders remained corrosion free for two years
- 3 of 6 cylinders developed stage 3 corrosion in streaks and bands from 60°-300° of the circumference of the piston travel area and from 1/8" to 1" wide.

## Engine #3 - High limit MIL-L-21260 Grade 2

- 5 of 12 cylinders remained corrosion free for two years
- 1 of 12 cylinders developed spotty stage 3 corrosion over entire piston travel area.
- 1 of 12 cylinders developed stage 1 corrosion over top half of piston travel area.
- 3 of 12 cylinders, no noticeable change from first annual evaluation.
- 1 of 12 cylinders, stage 3 corrosion over top half of piston travel area.
- 1 of 12 cylinders displayed spotty stage 1 corrosion over entire piston travel area.

## Engine #4 - Low limit MIL-L-21260 Grade 2

- 2 of 6 cylinders remained corrosion free for two years
- 3 of 6 cylinders developed stage 3 corrosion, 2" wide band for 360° of the circumference of the piston travel area.
- 1 of 6 cylinders, no change from first evaluation

## Engine #5 - VCI Oil.

- All 12 cylinders remained free of corrosion for two years

## Engine #6 - VCI Oil.

- All 12 cylinders remained free of corrosion for two years

DETAILED SUMMARY OF SECOND ANNUAL EVALUATION

Engine #7 - Left bank, VCI plugs plus low limit MIL-L-21260 oil

Right bank, VCI plugs only

11 of 12 cylinders remained corrosion free for two years

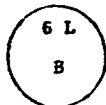
1 of 12 cylinders developed stage 3 corrosion, 1" wide band  
for 90° of circumference of piston travel area.

Engine #8 - Left bank, VCI plugs plus low limit MIL-L-21260 oil

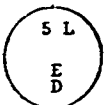
Right bank VCI plugs only

7 of 12 cylinders remained corrosion free for two years

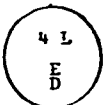
5 of 12 cylinders developed strips and spots of stage 2 corrosion from 1/4" to 2" wide on 60°-180° of the circumference  
of the piston travel area.



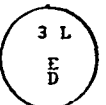
#2 &amp; 3 Corr Ent Cyl



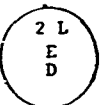
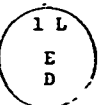
# 2 &amp; 5 Corr Ent Cyl



1" W #3 Corr 380°

Pulled

#3 Corr 360°

#3 Corr, one spot 1" W  
Two small spots 1/2" Diameter.

Spotty #3 Corr 360°

Tank, Combat, F.T. w/90  
MM, Gun M48A1  
USA NR. 30177806  
First Insp. 9-15-59  
Second Insp. 9-20-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

E - Electrofilm  
D - Detroit Licensee  
W - West Coast  
B - Bare  
1 - 6 Hr. of cylinders  
L - Left Bank  
R - Right Bank

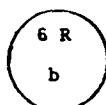
100 mile run of M48A1  
vehicle completed  
6-27-58

Processed with: Low Limit  
Grade 2 MIL-L-2126G Oil.

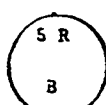
Pulled this cylinder  
Removed first and second  
inspection

All cylinders Boroscoped

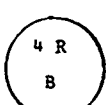
Date processed: 7-2-58



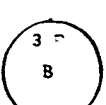
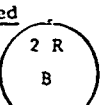
Spotty #2 &amp; 3 Corr Ent Cyl



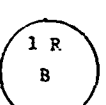
#3 Corr from 60° 1/4" to 1" W



No corrosion

1/2" W, 180°, #3 spotty  
Corr 180°Pulled

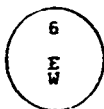
No corrosion



Small areas of Corr #1

ACCESSORY END

ENGINE NR. 2 AOS 895-3 SERIAL NR. 8207



No corrosion

Cun, Self-Propelled, F.T.  
Twin 40HP M42  
USA NR. 12F881

First Insp. 9-15-59  
Second Insp. 9-28-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

E - Electrofilm  
W - West Coast  
B - Bare

100 mile run of M42  
vehicle completed  
6-27-58.



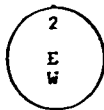
No corrosion

Processed with: High  
Limit Grade 2 MIL-L-  
21260 7-2-58.

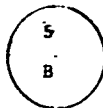
Pulled; This cylinder  
removed first and  
second inspection.

All cylinders Boroscoped

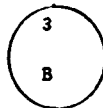
Date processed: 7-2-58



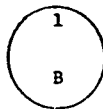
#3 Corr, near top 1" L  
and above ring travel



No corrosion



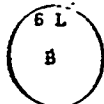
Same as first inspection  
plus 1" strip of #2 Corr  
extended from top of piston  
travel to bottom of Cyl

Pulled

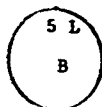
Several spotty streaks, #3  
Corr 60°

ACCESSORY END

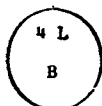
## ENGINE NR. 3 AVI 1790-7C SERIAL NR. 26003



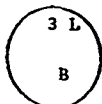
No corrosion



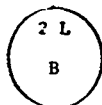
#3 Corr 1" W for 270°



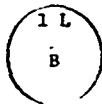
Spotty #3 Corr Ent Cyl



#3 Corr 1-1/2" W 300°

Pulled

No corrosion



Spotty #3 Corr top area

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 9A 1196

First Insp. 9-15-59  
Second Insp. 9-21-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

P - Phosphate  
B - Bare  
1 - 6 Nr. of cylinder  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
6-27-58.

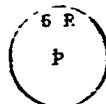
Processed with: High  
Limit Grade 2 MIL-L-  
21260 Oil.

Pulled: This cylinder  
removed first and second  
inspection.

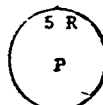
(Pulled) This cylinder  
removed second inspec-  
tion

All cylinders Boroscoped

Date processed: 7-2-58

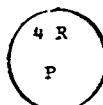


#2 Corr 1" x 4"

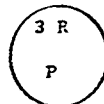


No corrosion

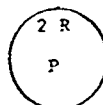
(Pulled)



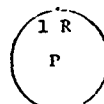
#2 Corr 1" x 4" vertical,  
spotty #1, Corr throughout  
Ent Cyl



No corrosion



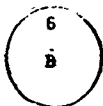
No corrosion  
(Pulled)



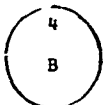
Spotty #1 Corr top area

ACCESSORY END

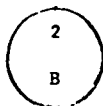
ENGINE NR. 4 AOS 895-3 SERIAL NR. 4967

#3 Corr spotty for  
360° top half Cyl

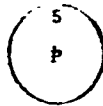
(Pulled)

#3 Corr 360° 2" W top  
of ring travel area.

(Pulled)

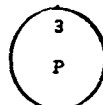
Same as first inspection  
with increased Corr.PulledGun, Self-Propelled, F.T.  
Twin 40MM M42,  
USA NR. 12D112First Insp. 9-15-59  
Second Insp. 9-21-60This is the results of  
the second inspection.CODE FOR CYLINDERSP - Phosphate  
B - Bare  
1 - 6 Nr. of cylinders100 mile run of M42  
vehicle completed  
6-27-58Processed with: Low  
Limit Grade 2 MIL-L-  
21260 Oil.Pulled: This cylinder  
removed first and second  
inspection(Pulled) This cylinder  
removed second inspection.

Date processed: 7-2-58

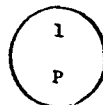


No corrosion

(Pulled)

#3 Corr 2" W 320° top of  
ring travel area.

(Pulled)

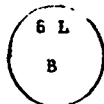


No corrosion

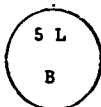
(Pulled)

ACCESSORY END

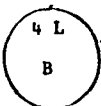
ENGINE NR. 5 AVI-1790-7C SERIAL NR. 21040



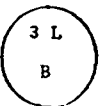
No corrosion



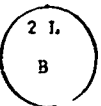
No corrosion



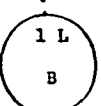
No corrosion



No corrosion



No corrosion

Pulled

No corrosion

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30177800

First Insp. 9-15-59  
Second Insp. 9-20-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 Hr. of cylinders  
L - Left Bank  
R - Right Bank

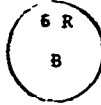
100 mile run of M48A1  
vehicle completed  
9-28-58.

Processed with VCI Oil.

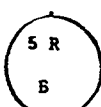
Pulled: This cylinder  
removed first and second  
inspection.

All cylinders Boroscoped

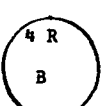
Date processed: 9-29-58



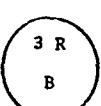
No corrosion



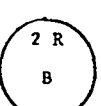
No corrosion



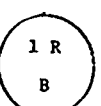
No corrosion



No corrosion



No corrosion

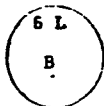
Pulled

No corrosion

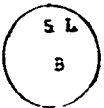
ACCESSORY END



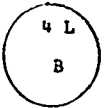
ENGINE NR. 6 AVI-1790-7C SERIAL NR. 16586



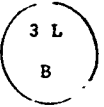
No corrosion



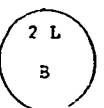
No corrosion



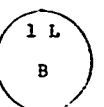
No corrosion



No corrosion



No corrosion



No corrosion

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30177735

First Insp. 9-15-59  
Second Insp. 9-20-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 Hr. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-58

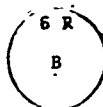
Processed with VCI Oil.

There were no cylinders  
removed.

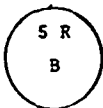
All cylinders Boroscoped

Date Processed: 9-29-58

ACCESSORY END



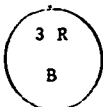
No corrosion



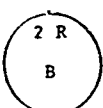
No Corrosion



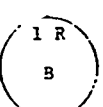
No corrosion



No corrosion

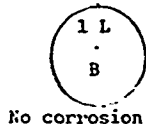
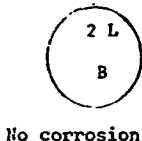
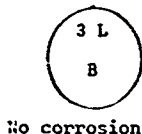
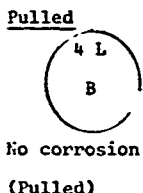
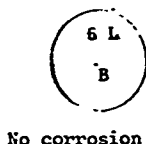


No corrosion



No corrosion

ENGINE NR. 7 AV-1790-3 SERIAL NR. 16620



Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30173160

First Insp. 9-15-59  
Second Insp. 9-20-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 Nr. of cylinders  
L - Left Bank  
R - Right Bank

100 Mile run of M48A1  
vehicle completed  
9-28-58

1 - 6 Left Bank Cylind-  
ers processed with Low  
Limit Grade 2, MIL-L-  
21260 plus V.C.I. plugs  
in spark plug openings.

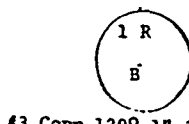
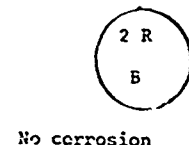
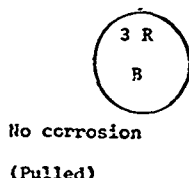
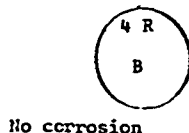
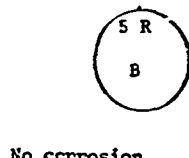
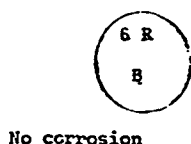
1 - 6 Right Bank Cylind-  
ers. No oil thru spark  
plug openings, only VCI  
plugs.

Pulled: This cylinder  
removed first and second  
inspection.

(Pulled) These cylind-  
ers removed second in-  
spection.

All cylinders Boroscoped

Date processed: 9-29-58



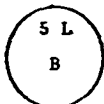
#3 Corr 120° 1"x3" 4

ACCESSORY END

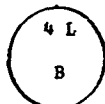
ENGINE NR. 8 AV-1790-B SERIAL NR. 51108



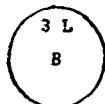
No corrosion



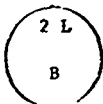
1/2" band #2 Corr 180°  
Pulled



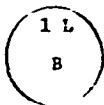
1/2" W strip #3 Corr  
60° top area.



Strip #1 Corr 90° bottom  
area  
(Pulled)



No corrosion



No corrosion

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 9A1195

First Insp. 9-15-59  
Second Insp. 9-20-60

This is the results of  
the second inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 Nr. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-58.

1-5 Left Bank, cylinders  
processed with Low Limit  
Grade 2, MIL-L-21260 plus  
V.C.I. plugs in spark  
plug openings.

1-6 Right Bank, cylind-  
ers processed with V.C.I.  
plugs only, no oil thru  
spark plug openings.

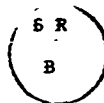
Pulled This cylinder re-  
moved first and second  
inspection.

(Pulled) These cylinders  
removed second inspection

All cylinders Boroscoped

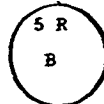
Date processed: 9-29-58

ACCESSORY END

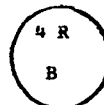


No corrosion

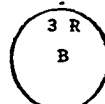
(Pulled)



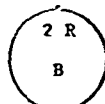
#1 Corr, 1/4"x2"



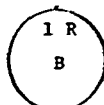
No corrosion



No corrosion



5 spots 1/4" W from 1/2"  
to 2" top area.



No corrosion  
(Pulled)

# GENERAL SUMMARY OF THIRD ANNUAL EVALUATION

VCI Oil (Eng 566) proved best by keeping 17 of 24 cylinders corrosion free for three years. The other seven cylinders which developed corrosion during the third year of storage were spotty and not near as severe as the other engines.

VCI crystals (Eng #7 & 8) alone or with MIL-L 2160 proved second best with 3 of 24 cylinders corrosion free 3 years, 15 of the 21 cylinders developed corrosion during third year of storage. Practically all the corrosion was confined to spots or bands 1/2" - 1" wide, 90° - 360° of the circumference of the piston travel area.

MIL-L-21260 oil displayed sufficient corrosion on half the cylinders to question satisfactory operation of the engine after reassembly without considerable rework and/or salvage.

There was a more noticeable difference in the performance of the two sources of MIL-L-21260 oil. One source considered borderline insofar as meeting the requirements of the specification did not perform as well as another source material that our qualification people regard as far above the minimum specification requirements. In the test these materials were designated as low limit and high limit accordingly.

The combination of a phosphate treatment plus MIL-L-21260 oil performed slightly better than the same oil on the bare cylinders, however, not sufficiently superior to warrant the time, cost and labor of phosphate coating each cylinder.

The use of electrofilm (combination lead, tin and graphite) with oil did no better than the same oil on bare cylinders. Also no difference was noted between the coating as applied by the parent company or one of it's licensees.

All cylinders were both boroscope inspected then removed for actual visual inspection. Generally speaking the comparison revealed the extent and degree of corrosion is most difficult to ascertain strictly by boroscope readings. Therefore, the findings on the detailed sheets for the third evaluation show the actual condition as determined by visual inspection after removal of the cylinders from the engine. Upon complete teardown, other components were checked for corrosion and/or deterioration. Engines were then reassembled, tested on a power pack test stand for efficiency of operation with particular emphasis on performance relating to the following characteristics and components.

Oil Pressure	Magnetos	Fuel Filter
Noise	Carburetors	Oil Filter Element
Blow By	Ignition Harness	
Stall Test (RPM	Generator	
Compression Readings	Starter	
of Each Cylinder)		

DETAILED SUMMARY OF 3RD & FINAL EVALUATION

## Engine #1 - Low Limit MIL-L-21260, Grade 2 Oil.

- 1 of 12 cylinders remained corrosion free for three years.
- 2 of 12 cylinders exhibited Stage 3 corrosion for the entire piston travel area.
- 1 of 12 cylinders exhibited Stage 2 & 3 corrosion spots over the entire piston travel area.
- 1 of 12 cylinders displayed Stage 3 corrosion for 2/3 of the entire piston travel area.
- 7 of 12 cylinders exhibited Stage 2 & 3 corrosion spots and bands for the entire circumference from 1" - 2" wide.

Upon reassembly and testing on a power pack test stand for efficiency of operation, the following deficiencies were noted.

- a) Oil pressure was 45 P.S.I. at 2800 RPM, acceptable is 60 - 70 P.S.I. Assumption is this was caused by worn bearings and not storage deficiency.
- b) Generator showed no change, probably caused by previous disassembly and/or workmanship and not deterioration.
- c) Governor was unserviceable. Not due to storage.

## Engine #2 - High Limit MIL-L-21260, Grade 2 Oil.

- 4 of 6 cylinders displayed Stage 2 & 3 corrosion on entire piston travel area.
- 2 of 6 cylinders displayed Stage 2 & 3 corrosion spots over entire piston travel area.

Upon reassembly and testing on a power pack test stand for efficiency of operation, no deficiencies were noted.

## Engine #3 - High Limit MIL-L-21260, Grade 2 Oil.

- 2 of 12 cylinders showed no corrosion after three years.
- 1 of 12 cylinders displayed Stage 2 & 3 corrosion on the entire piston travel area.
- 4 of 12 cylinders showed Stage 2 corrosion spots on the entire piston travel area.
- 3 of 12 cylinders displayed stage 3 corrosion bands 1-1/2" - 2" wide for 300°-360° of the circumference of the piston travel area.
- 1 of 12 cylinders showed stage 3 corrosion in one area of the piston travel area 4"x3".
- 1 of 12 cylinders displayed Stage 1 corrosion for top half of piston travel area.

Upon reassembly and testing on a power pack test stand for efficiency of operation, engine would not start due to improper timing.

Engine # 4 - Low Limit MIL-L-21260, Grade 2 Oil.

All 6 cylinders corroded.

1 of 6 cylinders, Stage 3 corrosion over entire piston travel area.

1 of 6 cylinders, Stage 2 & 3 corrosion spots over entire piston travel area.

4 of 6 cylinders, Stage 3 corrosion bands 1-1/2"-2" wide for 300°-360° circumference of piston travel area.

Upon reassembly and testing on a power pack test stand, the only deficiency was the ignition harness which was damaged due to the handling in the three teardowns.

Engine #5 - VCI Oil.

3 of 12 cylinders remained corrosion free for 3 years.

3 of 12 cylinders, Stage 2 corrosion spots on entire piston travel area.

1 of 12 cylinders, Stage 2 corrosion band 1/8" wide for 180° of circumference of piston travel area.

Upon reassembly and testing on a power pack test stand, no operating deficiencies were found.

Engine #6 - VCI Oil.

6 of 12 cylinders remained corrosion free for three years.

2 of 12 cylinders Stage 2 corrosion spot 1/2"-2-1/2" wide by 2-1/2" long.

1 of 12 cylinders Stage 1 & 2 corrosion spots on lower half of piston travel area.

Upon reassembly and testing on a power pack test stand no operating deficiencies were noted.

Engine #7 - Left Bank - VCI plugs plus Low Limit MIL-L-21260, Grade 2 Oil atomized through spark plug openings. Right Bank - VCI plug only.

1 of 12 cylinders remained corrosion free for three years.

6 of 12 cylinders Stage 2 corrosion spots over entire piston travel area.

3 of 12 cylinders Stage 2 corrosion spots over lower half of piston travel area.

2 of 12 cylinders, Stage 3 corrosion band 1/2"-1" wide, 180°-360° circumference of the piston travel area.

Upon reassembly and testing on a power pack test stand the following operating deficiencies were noted.

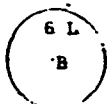
- a) Compression was low on all 6 cylinders of the right bank and 1 cylinder slightly low on left bank.
- b) Stall test (P.F.'s) read 2300 instead of the minimum 2400.
- c) Blow By rejectable.

All above deficiencies presumably due to faulty timing caused by the teardown and not any deterioration and/or corrosion.

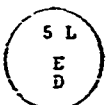
Engine #8 - Same as 7.

- 2 of 12 cylinders remained corrosion free for three years.
- 2 of 12 cylinders Stage 2 & 3 corrosion spots for entire piston travel area.
- 8 of 12 cylinders, Stage 2 & 3 corrosion band 1/2"-1" wide, 180°-360° circumference of piston travel area.
- 4 of these same 8 showed additional strip of stage 3 corrosion 1/4" wide, 60°-180° circumference of piston travel area.

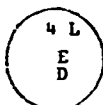
Upon reassembly and testing on a power rack test stand no operating deficiencies were noted.



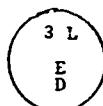
#3 Corr 180°, 1-1/2" 2"  
W top of Cyl



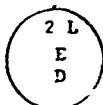
#3 Corr Ent Cyl



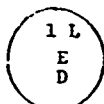
#3 Corr 360° 1"-1-1/2"W  
top of Cyl



#2 & 3 Corr spots 1" W  
360° top of Cyl



#2 & 3 Corr spots Ent  
Cyl



#3 Corr 360° 2" W top  
of Cyl

Tank, combat, F.T. w/90  
MM. Gun, M48A1  
USA NR. 30177806

First Insp. 9-15-59  
Second Insp. 9-26-60  
Third Insp. 10-12-61

This is the results of  
the third inspection.

#### CODE FOR CYLINDERS

E - Electrofilm  
D - Detroit Licensee  
W - West Coast  
B - Bare

1-6 No. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
6-27-58, processed with  
low limit Grade 2 MIL-L-  
21260 Oil.

Pulled this cylinder.  
Removed first and second  
inspection.

All cylinders pulled.

All cylinders Borecoped

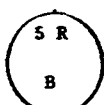
First & Second Inspection

Date processed: 7-2-58

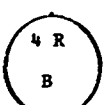
ACCESSORY END



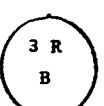
#3 Corr Ent Cyl.



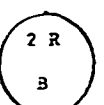
#3 Corr 360° 1-1/2" 2"W  
top of Cyl.



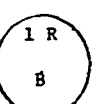
#2 & 3 Corr spots 1/2" W  
top of Cyl



#2 & 3 Corr 360° 1" W top  
of Cyl



No corrosion



2/3 Ent Cyl #3 Corr top  
half



ENGINE NR. 2 AOS 895-3 SERIAL NR. 8207

6

E  
W

# 2 &amp; 3 Corr Ent Cyl

Gun, Self-Propelled, F.T.  
Twin 40MM, M42  
USA HP. 12F881First Insp. 9-15-59  
Second Insp. 9-20-60  
Third Insp. 10-12-61This is the results of  
the third inspection.CODE FOR CYLINDERSE - Electrofilm  
W - West Coast  
B - Bare100 mile run of M42 veh-  
icle completed 6-27-58.Processed with high Limit  
Grade 2 MIL-L-2126<sup>0</sup> Oil  
7-2-58.

5

B

#2 &amp; 3 Corr spots Ent Cyl

4

E  
W

#2 &amp; 3 Corr Ent Cyl

3

B

#2 &amp; 3 Corr Ent Cyl

Pulled: This cylinder  
removed first and second  
inspection.All cylinders pulled  
All cylinders microscoped;  
First & Second Inspection  
Date processed: 7-2-58

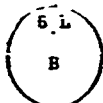
2

E  
W#2 & 3 Corr spots Ent  
Cyl

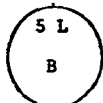
1

B

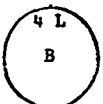
#3 Corr Ent Cyl



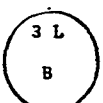
# 1 & 2 Jorr spots Ent Cyl



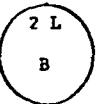
#3 Corr 1-1/2" W top of Cyl



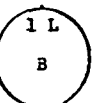
#3 Corr 360° 2" W top of Cyl



#3 Corr 300° 1-1/2" W top of Cyl



#2 Corr spots Ent Cyl



#2 & 3 Corr Ent Cyl

Tank, combat, F.T. w/90  
M48A1  
USA NR. 9A 1196

First Insp. 9-15-59  
Second Insp. 9-21-60  
Third Ins 10-12-61

This is the results of the third inspection.

CODE FOR CYLINDERS

P - Phosphate  
B - Bare  
1 - 6 No. of cylinder  
L - Left Bank  
R - Right Bank

100 mile run of M48A1 vehicle completed 6-27-58.

Processed with High Limit Grade 2 MIL-L-21260.01l

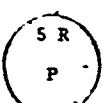
Pulled: This cylinder removed first and second inspection.

(Pulled) This cylinder removed second inspection

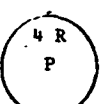
All cylinders pulled  
All cylinders Boroscoped  
First & Second Inspection  
Date processed: 7-2-58



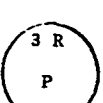
#2 & 3 Corr spots 4"x3"



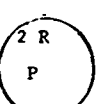
No corrosion



#2 & 3 Corr spots Ent Cyl.



#1 Corr spots Ent Cyl



No corrosion



#1 Corr top of Cyl

ENGINE NR. 4 AOS 895-3 SERIAL NR. 4967



#3 Corr Ent Cyl

Gun, Self-Propelled, F.T.  
Twin 40 MM, M42  
USA NR. 12D112

First Insp. 9-15-59  
Second Insp. 9-21-60  
Third Insp. 10-12-61

This is the results of  
the third inspection.

CODE FOR CYLINDERS

P - Phosphate  
B - Bare  
1 - 6 No. of cylinders

100 mile run of M42 veh-  
icle completed 6-27-58.

Processed with Low Limit  
Grade 2 MIL-L-21260 Oil.

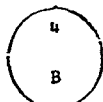
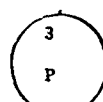
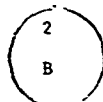
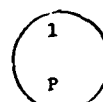
Pulled: This cylinder  
removed first and second  
inspection.

(Pulled) This cylinder  
removed second inspection  
All cylinders pulled.  
Date processed: 7-2-58

All cylinders Boroscoped  
first and second inspec-  
tion.

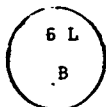


#1 &amp; 2 Corr spots Ent Cyl

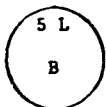
#3 Corr 360° 2" W at  
top of Cyl#3 Corr 360° 2" W at top  
of Cyl#3 Corr 300° 1-1/2" W  
at top of Cyl#2 Corr spots 1-1/2" W at  
top of Cyl

ACCESSORY END

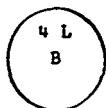
ENGINE NR. 5 AVI-1790-7C SERIAL NR. 2104D



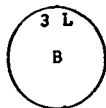
No corrosion



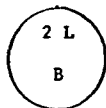
#1 &amp; 2 Corr spots Ent Cyl



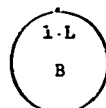
No corrosion



No corrosion



#2 &amp; 3 Corr spots Ent Cyl



No corrosion

Tank, combat, F.T. w/90  
M4 Gun, M48A1  
USA NR. 30177800

First Insp. 9-15-59  
Second Insp. 9-20-60  
Third Insp. 10-12-61

This is the results of  
the third inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 No. of cylinders  
L - Left Bank  
R - Right Bank

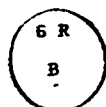
100 mile run of M48A1  
vehicle completed  
9-28-58.

Processed with VCI Oil.

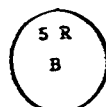
Pulled: This cylinder  
removed first and second  
inspection.

All cylinders pulled  
All cylinders Boroscoped  
First and Second Inspection.

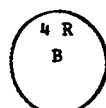
Date processed: 9-29-58



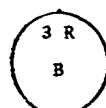
No corrosion



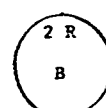
No corrosion



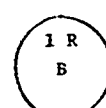
#1 Corr spots Ent Cyl



#2 Corr 1/8" W 180° center  
of Cyl



No corrosion

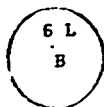


No corrosion

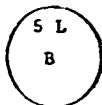
ACCESSORY END

14

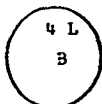
ENGINE NR. 6 AVI-1790-7C SERIAL NR. 16586



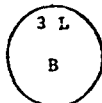
#2 & 3 Corr spot 1-1/2"  
x 2-1/2" center of Cyl



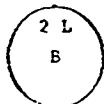
No corrosion



No corrosion



No corrosion



No corrosion



No corrosion

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30177735

First Insp. 9-15-59  
Second Insp. 9-20-60  
Third Insp. 10-12-61

This is the results of  
the third inspection.

CODE FOR CYLINDERS

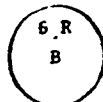
B - Bare  
1 - 6 No. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-58

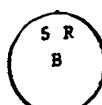
Processed with VCI Oil.

There were no cylinders  
removed.  
All cylinders pulled  
All cylinders Boroscoped  
First and Second Inspection.  
Date processed: 9-29-58

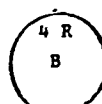
ACCESSORY END



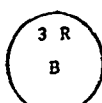
No corrosion



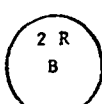
No corrosion



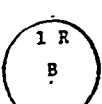
#1 & 2 Corr spots lower  
half of Cyl



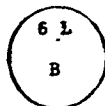
No corrosion



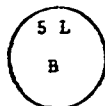
No corrosion



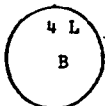
#1 & 2 Corr spots 1/2" W  
45° top of Cyl



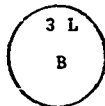
#3 Corr spots Ent Cyl



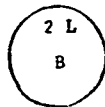
#2 &amp; 3 Corr spots Ent Cyl



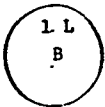
#1 &amp; 2 Corr spots Ent Cyl



No corrosion



#3 Corr spots Ent Cyl



#2 &amp; 3 Corr spots Ent Cyl

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 30173160

First Insp. 9-15-59  
Second Insp. 9-20-60  
Third Insp. 10-12-61

This is the results of  
the third inspection.

CODE FOR CYLINDERS

B - Bare  
1 - 6 No. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-59.

1-6 Left Bank Cylinders  
processed with Low Limit  
Grade 2 MIL-L-21260 plus  
V.C.I. plugs in spark  
plug openings.

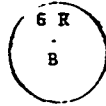
1-6 Right Bank Cylinders  
No oil thru spark plug  
openings, only V.C.I.  
plugs.

Pulled: This cylinder re-  
moved first and second  
inspection.

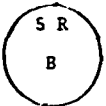
(Pulled) These cylinders  
removed second inspection  
All cylinders pulled  
All cylinders Boroscoped  
First and Second Inspec-  
tion.

Late processed: 9-29-58

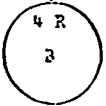
ACCESSORY END



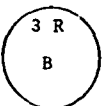
#1 &amp; 2 Corr spots lower half of Cyl



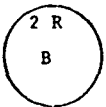
#3 Corr 1/2" W 360° top of Cyl



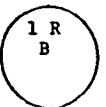
#1 &amp; 2 Corr spots lower half of Cyl



#2 &amp; 3 Corr spots Ent Cyl

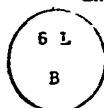


#2 &amp; 3 Corr 180° 1" W top of Cyl



#2 &amp; 3 Corr spots lower half of Cyl

ENGINE NO. 8 AV-1790-B SERIAL NR. 51108



#3 Corr 1/2" W 360° top of Cyl

Tank, combat, F.T. w/90  
MM Gun, M48A1  
USA NR. 9A 1195

First Insp. 9-15-59  
Second Insp. 9-20-60  
Third Insp. 10-12-61

This is the results of  
the third inspection.

CGDF FOR CYLINDERS

B - Bare  
1 - 6 No. of cylinders  
L - Left Bank  
R - Right Bank

100 mile run of M48A1  
vehicle completed  
9-28-58

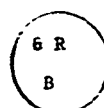
1-5 Left Bank Cylinders  
processed with Low Limit  
Grade 2 MIL-L-21260 plus  
V.C.I. plugs in spark  
plug openings.

1-6 Right Bank Cylinders  
processed with VCI plugs  
only, no oil thru spark  
plug openings.

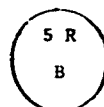
Pulled: This cylinder re-  
moved first and second  
inspection.

(Pulled) These cylinders  
removed second inspection  
All cylinders pulled  
All cylinders Boroscoped  
First and second inspec-  
tion.

Date processed: 9-29-58

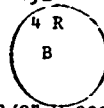


#2 &amp; 3 Corr 1/2" W 360° at top of Cyl

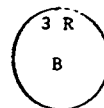


#3 Corr 1/2" W 360° at top of Cyl.

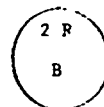
#3 Corr spot 1/4" W 60° center of Cyl



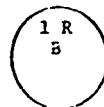
#3 Corr 1/2" W 360° top of Cyl



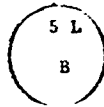
#2 &amp; 3 Corr spots Ent Cyl



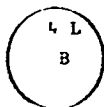
#3 Corr 1/2" W 180° top of Cyl



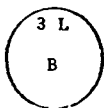
No corrosion



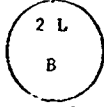
#2 &amp; 3 Corr 1/2" W 180° top of Cyl



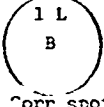
#3 Corr 3/4" W 360° top of Cyl



#2 &amp; 3 Corr spots 1" W top of cyl 360°



No corrosion



#2 &amp; 3 Corr spots Ent Cyl

ACCESSORY END

PHOTOGRAPHS

- FIGURE 1 - View of outdoor storage area showing some of the combat vehicles in which test engines were installed.
- FIGURE 2 - View of evaluation area where power pack assemblies (engine, transmission, fans, shroud) after disassembly from vehicles were brought in for tear-down. Engines in the rear are being disassembled with a removed cylinder assembly shown on the table.
- FIGURE 3 - View of test engine (AV 1790) from accessory or front end with fan and shroud in background. A removed cylinder assembly on the table. Another cylinder being boroscoped while still assembled to the engine. Boroscopes were always inserted through the spark plug openings (2 to each cylinder) for evaluation purposes of the interior cylinder area.
- FIGURE 4 - View of test engine AV 1790 from accessory or front end already considerably disassembled and being further torn down for final evaluation.
- FIGURE 5 - View of cylinder assembly removed from engine looking into the interior area showing the bottom of the exhaust valve, intake valve and spark plug.





FIGURE 1

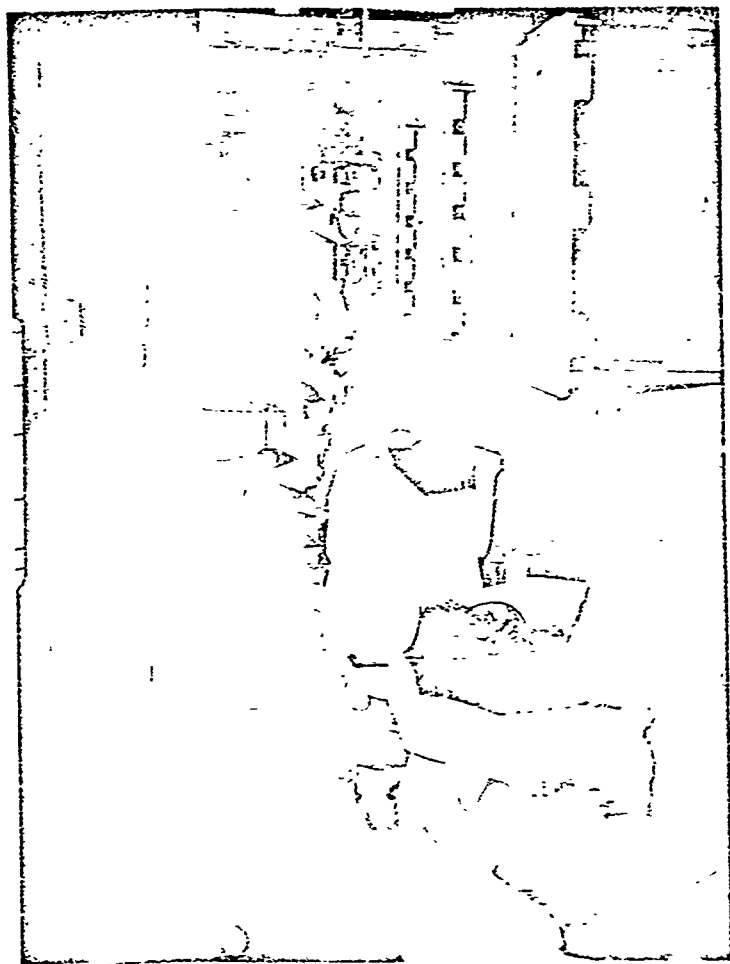


FIGURE 2

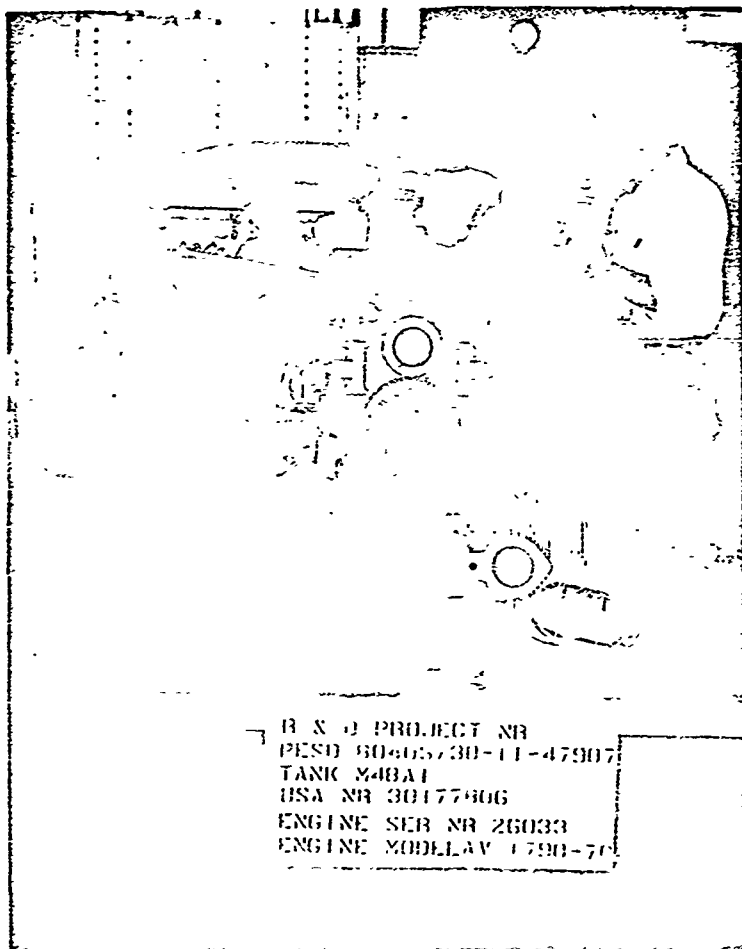


FIGURE 3

2

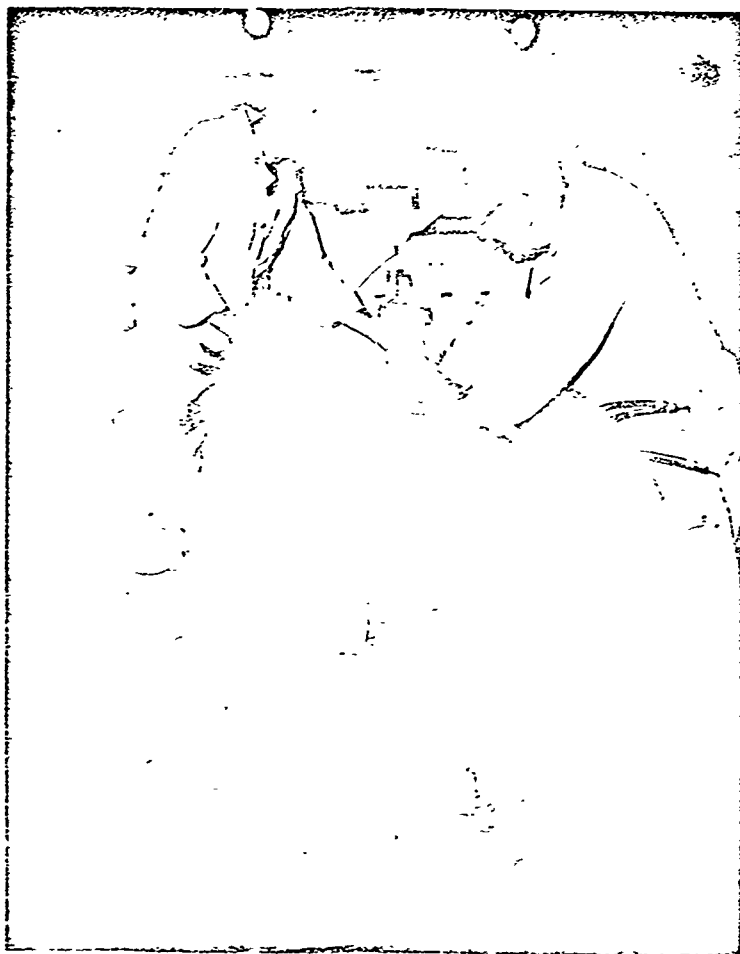


FIGURE 4

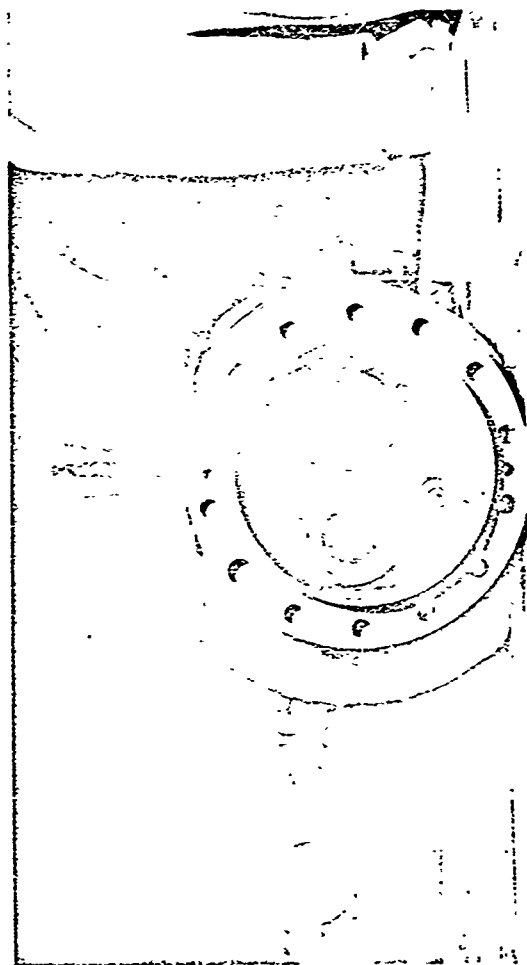


FIGURE 5

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ENGINE CORROSION STUDY 1. Engine Cor-  
Final Report, Phase I 56 pp. rosion Study  
Tables

PURPOSE - To attempt to increase the reprocessing cycle of installed en-  
gines in vehicles stored outdoors from the presently used one year to a  
minimum of three years. Despite improvements in application techniques,  
corrosion still occurs primarily in the cylinder area in less than one  
year. By the use of newly developed or improved presently used preserva-  
tive materials it is possible that maintenance in storage reprocessing  
operations can be greatly reduced.

RESULTS - VCI oil used in the test proved far superior to the presently  
used MIL-L-21260 oil after a minimum of three years outdoor storage under  
actual conditions. Of 16 cylinders (4 test engines) using the VCI oil 13  
were corrosion free after three years. The other 3 cylinders developed  
spotty and not too severe corrosion during the third year of storage.  
MIL-L-21260 oil displayed sufficient corrosion on 11 of 14 cylinders to  
question satisfactory operation of the engine after reasonably without  
considerable rework and/or salvage. Half of the cylinders showed corrosion  
in the first year.

CONCLUSIONS - There was no apparent attack from the VCI oil or VCI  
crystals on non-ferrous or non-metallic components of the engine. The two  
greatest causes of corroded cylinders or engine areas (a) Temperature con-  
ditions that produce alternate condensation & evaporation of moisture.  
(b) Combustion products producing an acidic environment.

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